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A SHORT THEORY OF QUARTER WAVE MATCHING TRANSFORMERS

.. By Alec H. Clyne VK3VX ..

INTRODUCTION. A question was recently asked - "when a quarter wave matching transformer is used to match a transmission line to the centre of a half wave antenna, why is it that the characteristic impedance of the matching transformer must be the geometric mean of the impedances of the transmission line and of the antenna at its centre."

The author will endeavour to answer this question in the simplest manner, but to do this it is first necessary to have the right appreciation of the fundamentals leading up to this subject.

CHARACTERISTIC IMPEDANCE. The characteristic impedance of a transmission line is the impedance which the line presents to the passage of an alternating current and is equal to

$$\sqrt{\frac{L}{C}}$$

where L is the distributed inductance of the line and C the distributed capacity, BOTH PER UNIT LENGTH OF TIME. These quantities are of course dependent on the conductor sizes and spacing and the relation between all these quantities is too well known to be repeated here.

STANDING WAVE RATIO.: When a transmission line is terminated in a resistance equal in value to the characteristic impedance, no standing waves will appear on the line, but if the resistance and the characteristic impedance differ, then standing waves will appear.

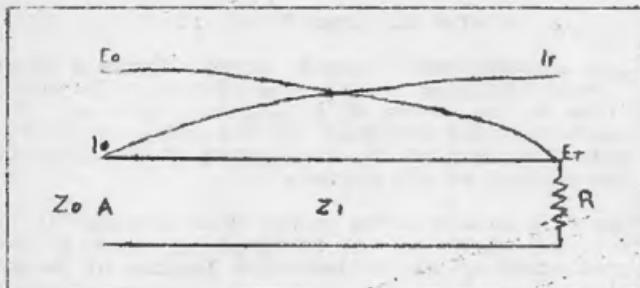
Furthermore the ratio between nodal and antinodal values of the standing wave current (or voltage) can be related to the characteristic impedance and the terminating resistance

thus :-

$$\text{Standing wave ratio} = \frac{Z_1}{R}$$

Where Z_1 = Characteristic impedance
 R = terminating resistance.

QUARTER WAVE TRANSFORMER. Let us go on to consider now a transmission line of characteristic impedance Z_1 a quarter wave long and terminated in a resistance R , as shown in the diagram.



If the line be fed by a generator at A standing waves will exist and the standing wave ratio will be :-

$$\frac{Z_1}{R}$$

Let the impedance looking into the end at A by Z_0 . Since at A the curve of voltage is at a point of inflection, (i.e., its slope is zero, or horizontal) the voltage and current are in phase and the impedance Z_0 is resistive, therefore Z_0 may be evaluated as :-

$$\frac{E_0}{I_0}$$

Also $Z_0 = R = \frac{E_0}{I_0}$

But $E_0 = E_r \times \frac{Z_1}{R}$ $(\frac{Z_1}{R} = \text{standing wave ratio})$

And $I_0 = I_r \times \frac{Z_1}{R}$

$$\begin{aligned} \text{Therefore } Z_0 &= \frac{E_0}{I_0} = \frac{E_r \times \frac{Z_1}{R}}{I_r \times \frac{Z_1}{R}} = \frac{E_r Z_1}{I_r R} \times \frac{Z_1}{I_r Z_1} \\ &= \frac{Z_1^2 \times E_r}{R^2 I_r^2} \end{aligned}$$

$$Z = \frac{Z_1}{\sqrt{Z_0 R}}$$

From which $Z_1 = \sqrt{Z_0 R}$

So we see that if an impedance Z_0 is to be matched to a resistance R the match can be accomplished by interposing a quarter wave length of transmission line, the characteristic impedance of which must be

$$\sqrt{Z_0 R}$$

FOOTNOTES:

1. Note that the above relation applies to either end of the quarter wave line so that the match is theoretically perfect, and therefore standing waves cannot appear either on the transmission line (feeders) or on the quarter wave section.
2. The fact that the required impedance works out to the geometric mean of the impedances to be matched is apparently coincidental, it however provides a convenient means of memorising the equation, provided of course that one also remembers what constitutes a geometric mean.
3. The above system has come to be known as the "Q-bar matching transformer" and has achieved a certain popularity, due, the author suspects, to its little understood theory and its relatively spectacular appearance, for in practice it has no advantage over the delta match, indeed it is more difficult to adjust, and the mechanical problem alone, of supporting a heavy quarter wave for, say, the 7Mc band is sufficient to make most hams think twice.
4. And what of the cost? Since the impedance of the quarter wave is relatively low it must be solidly built to achieve stability, which means using copper tubing of say about half an inch diameter, which costs money.
5. Altogether it would seem that Q-bars are a doubtful proposition, unless the user is prepared to put considerable care and patience into their construction, suspension and adjustment, when they should be at least as good as any other matching device.

Mr. R. A. Priddle VK2RA has supplied another method of attack to the problem. Mr. Priddle writes:-

"the equation $Z_0 = \sqrt{Z_1 Z_2}$ is merely a re-statement of the equation for the input impedance of a quarter wave section (A.R.R.L. Handbook 1942 Pg168) i.e.

$$Z_1 = \frac{Z_0^2}{Z_2}$$

Otherwise it may be derived from consideration of standing wave ratios, which are of course equal to the ratio of the impedance mismatch.

Taking the example quoted, suppose the antenna current at centre is 1 ampere; then voltage at centre is $1 \times 72 = 72$ volts. Now impedance mismatch

$$= \frac{208}{72} = 2.88$$

Then current at far end of the quarter wave section is $1/2.88$ amp. and voltage at far end is 72×2.88 divided by $1/2.88 = 72 \times 2.88 = 300$ ohms. which matches the 600 ohm lines.

The actual equation $Z_0 = \sqrt{Z_1 Z_2}$ can be developed by substituting 10, Eo Z0 etc. in the above argument.

Note that Z_0 is the "mean proportional" between Z_1 and Z_2 or in other words that $Z_0 = \sqrt{Z_1 Z_2}$ because if:-

$$\frac{Z_1}{Z_1} = \frac{Z_0}{Z_0}$$

$$Z_0 = \sqrt{Z_1 Z_2}$$

$$Z_0^2 = Z_1 Z_2$$

Divide by $Z_0 Z_1$

$$\frac{Z_0}{Z_1} = \frac{Z_2}{Z_0}$$

In other words the mismatch at either end of the Q section are equal.

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ANOTHER PROBLEM

No doubt every amateur has lying around his shack many old electrolytic condensers which have seen better days, due to excessive leakage and in consequence loss of capacitance.

In these days when wet type of electrolytic condensers are unprocureable we are hopeful that some of our readers may have ideas for the re-juvination of these old condensers.

If you have any ideas or better still concrete methods of bringing to life these old condensers let us have it so that we can publish it for the information of other readers.

...000...

WOULD YOU BELIEVE IT... A neighboring ECL once wrote to W8VEW as follows: "Please forgive the writing of this note, but I had to tell you how much I enjoy listening to your station even though it isn't polite to listen in. It comes in very plain on my small set. Hope you don't mind too much." After due consideration W8VEW decided to forgive him. "But don't let it happen again" he added.....QST.

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HOLES IN THE IONOSPHERE

-- Waves lost in Space --

A short note in a recent issue of the Wireless World gives some interesting suggestions as to the manner in which the above phenomenon takes place.

During magnetic storms the ionic density in the F layer is known to decrease very considerably, and failure of short wave communication to occur, because the ionic density becomes insufficient to ensure refraction of the waves. There is evidence that this effect is brought about by the action of streams of corpuscles which arrive in the ionosphere from the sun, but the precise nature of their action is not yet understood. The suggestion as to how this effect may occur is as follows.

Assuming that the corpuscular stream is in itself neutral, i.e. composed of equal numbers of positive and negative particles, it is suggested that on entering the atmosphere the electrons would be retarded much sooner than the positive ions, the former coming to a standstill in the higher atmosphere while the latter penetrate down as far as the E layer.

When this has occurred a large electric force exists between the E and F layers, and this, together with the force of the earth's magnetic field, causes a violent drift of the electrified particles in the F layer, which is in effect a west to east current in the layer. In the E layer there is a tendency for an opposite drift to occur, but owing to the large molecular density at this height the current is much smaller.

The ionosphere is the region of the earth where the electric force was set up, is thus swept fairly clear of electrons and positive ions and a big hole in the refracting layer is thus produced. Through this the radio waves can penetrate and so be lost in space.

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ITEM ... An electronic micrometer accurate to .000002 inch (two millionths of an inch) is being used to measure the stretch of a bolt which holds together two sections of the crank-shaft of an aircraft engine. The bolt is tightened under 1500 foot-pounds tension until it stretches exactly .008 inch.

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"SEAFARERS, FOOTSLOGGERS and SKYWAYMEN"

(Incorporating...Slouch Hats & Forage Caps) Hi!

... By 2YC ...

"Struth I dunno...." at least that's what the Sentimental Blake of immortal fame said about names....but I dunno....I think the lads of the H.M.A.S. Lonsdale have taken "poetic Licence," to their suggestion for our title. Oh, but they are cunning...one sets them a task to provide me with a CAP for the Navy...tricks 'em bad and they switch the whole line...so I leave it to our 5000 ham readers to adjudicate on the matter. From Canberra being the Fed. Capital, I hope to have most learned comment. Hi! I am informed that the services are placed in the order of seniority as per "Nelson or Trafalgar." I had a vague idea of Alfred The Great, myself or some such laddie...but I'm a mere civilian so I am VERY neutral. The rest of the "Lonsdale" news being somewhat libellous I will place in inverted Commas. Hi!

"Harry 3IR has a great job at the moment...instructing WRANS in the gentle art of brassbounding. I understand he is a very popular instructor, by the way....but let's not let our imagination wander. (Possibly he gives them one of those Photos of himself as 1st Class Op...???? 2YC). Cap'n Bligh, 3UH is preparing for sea again...uke and all...just in case another one goes down. In the meantime so rumour has it he is QRL with the charming sister of 4GJ.

SSP seems to be busy, notwithstanding the "ham ban," as he recently sent over an order for gear. And I filled it! How's that for influence. SMV also ordered a pair of Test Prods. What is wrong with VK5? I notice a sad lack of notes from my old home town...and I'would seem there's a sad lack of gear. (Wish there wasn't such a "complete" lack of notes. Hi! 2YC)

Noticed an error in January QST. They refer to their Colleagues in Australia and their official journal "Break-In."

And now 'tis Harry's turn to punch the keys. "Well, both the Seafarers unfortunately were unable to attend last month's Vic. Division meeting. 3MV was at sea acting on an unfounded idea that a few weeks sea air was good for ones system. Now he is back...says its the vilest form of propaganda issued by non-seafering medicos. Anyway did at least keep 3MV away from the 3GJ. 3IR too busy QSOing brand new girl friend (Nr.622) filling her with sweet words and lots of grog. Ultimate intentions doubtful...still waiting for 31st March to celebrate twin birthdays with a certain very attractive luscious blonde Dental Nurse,and then I think the boat should have had "Little" in front

(Continued on page 9)

SUPERCONDUCTIVITY.

This phenomenon will probably for long save us from too smug a complacency about our understanding of the electrical behaviour of metals. There are a few laboratories, notably that in the University of Leyden, in which has been developed the peculiar and difficult technique of experimenting at temperatures more than 260 degrees centigrade below that of ice and within the last half dozen degrees above the absolute and unattainable zero of -273 degrees.

Here in banks of liquified helium gas, metallic conduction "runs wild." According to theory specific resistance ought to diminish steadily to zero at the absolute temperature zero. Actually it often tends to break away as if intending to finish as a very minute "residual" resistance. But many metals reverse this tendency by suddenly losing all their resistance several degrees above the zero. This is known as "super-conductivity" and though it has been said that we only have to induce this virtue at ordinary temperatures to solve many of the power engineers difficulties, he would face a new nightmare if we succeeded.

Actually the transition temperature at which this strange effect sets in has been raised by alloying, but only a degree or two.

Direct resistance measurement here becomes weird and unmanageable, but one sidelight from familiar radio constants is of interest. We know that when a potential is applied or removed, the change in current is not completed quite instantaneously, but except for an instance of large choke size takes about one thousandth to one millionth of a second.

On a famous occasion, the Leyden physicists induced a current in a metal ring immersed in liquid helium gas at a few degrees above absolute zero, then removed the source of potential and sent the whole apparatus to an English scientific gathering by aircraft; so complete had been the loss of resistance in superconductivity that the fall of current took hours instead of micro-seconds, and the English gathering found the current still running.

ITEM... Black crackle finish which has become filled with dust may be made to look like new by wiping with a clean rag soaked in any light oil. The oil should be allowed to remain on the surface for an hour and then thoroughly wiped off.

W3ERV..QST.

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ITEMS OF INTEREST

A method of preventing jamming of radio messages while still maintaining secrecy has recently been patented by Francois G. Henroteau of Ottawa, Canada. This is accomplished by use of a key plate which varies the frequency of the transmitter in an irregular manner according to a pattern on the plate. A similar key plate at the receiving end removes the distortion. If the enemy should happen to find out the pattern the key plates can be changed.

China's Transmitters:- The Chinese have established at Chungking the headquarters of the broadcasting service which now operates a dozen transmitters. The chief station is the medium wave 75KW transmitter XGOA which has been transferred from Nanking to the present Chinese Capitol. Also situated at Chungking are two short wave transmitters each of 35KW. There is also a 10KW short wave transmitter in the province of Kweichow and a 60KW medium wave transmitter in the province of Yenan. The Chungking transmitting apparatus has been installed in bomb-proof shelters within the hills on which the city is built.

QST for February publishes details of a new electronic device which signals and measures ice forming on airplanes in flight, and automatically operates the planes' de-icers. The ice indicator provides the pilot with information on the thickness and the rate of accumulation of ice on the exposed plane surfaces and permits the de-icing equipment to be turned on at the exact moment it becomes most efficient. The indicator which uses electronic principles for its operation is composed of three separate units. A pick-up or sensing element is mounted on the wing or plane surface where ice accretion is to be measured. This element is very small and is set flush with the plane so as not to disturb the airflow. The element is connected to an amplifier inside the wing, which in turn is connected to a power supply unit. The latter does the actual work of turning on the de-icers and registering the accumulation of ice on an instrument on the dash. The entire equipment weighs less than five pounds.

Argentina has opened up the 5 metre ham band, and in order to create a good supply of radio operators has made the requirements for obtaining amateur licenses much simpler.

air at their main transmitting station.

VK2AWF still remains a land-sailor and works lots of DX for the Navy. Roll on for the duration says Jack.

VY2ACG also just another land-lubber and looks after an 8KW rigs and six or seven smaller outfits for the U.S. Navy.

VK4RF...Ahem! STILL leading a quiet life more or less. (but still able to remember A.R. needs notes, thanks very much. 2YC). Hair is gradually turning grey with worry teaching WRANS how to work DX for the silent service. Now quite Blaze about handling P-120s and anything else the US like to give us...what say 2ANP? HI! J

Thanks OM's for all the news...as I've said and must say again.. six other correspondents as keen as the Canberra...Little...oh I mean FME Lonsdale group and everything in this Column whatever name we publish it under would be fb. Lastly I wish to thank...ahem!... one of my friends of high rank who spent an evening here...told me lots of lovely news of lots of Hams you'd all like to hear about and on leaving remarked... "of course, Jim, that all for yourself-f, Don't get me 'c'f that in Slouch Hats and Forage Caps...wouldn't it be like seeing "non-existent" Spitfires flying around the sky. HI!

Another lastly...I hear Johnny Traill is down in VK3 doing quite a bit of "posting"...I say Johnny how about getting a WAAF to post me those NOTES promised a year ago...HI!

All notes to Jim Corbin, 78 Melrose Street, Eastlakes N.S.W. or if you like to 3RJ? R.A.A.F. Pt. Piper.

D I V I S I O N A L N O T E S

.. Federal Headquarters ..

At the March General Meeting of the Federal Executive discussion centred around the operations of the Prisoner's of War Fund. Councillors were informed that the balance of the Fund was now £25/14/0 and that it was understood that the Victorian Division had also collected a considerable sum. The Chairman pointed out that the Red Cross Society was the only body permitted to send parcels of food but unfortunately that body could not guarantee delivery to any specified individual. Next of kin are the only persons permitted to forward clothing. Other persons may send books, games, playing cards etc.

It was decided that a cash donation be made to the Red Cross Prisoner's of War Fund realising that this would help any Amateur in a P.O.W. camp indirectly and that an endeavor to be made to arrange some form of Roster with the next of kin regarding other types of parcels.

NEW SOUTH WALES DIVISION.

The usual monthly General Meeting of the Division was held at V.N.C.A. Buildings on Thursday 15th March. The attendance as at previous meetings was quite large and reminiscent of pre-war days. The Chairman extended a welcome to Flight Lieutenant Harry Myers VK2VN and Bill Sievers VK3CB.

The Chairman informed the Meeting that Council, acting under the powers conferred upon it by the Articles and a memorandum of Association had elected the following Office Bearers for the ensuing year:-

President and Chairman	-	R. A. Priddle	VK2RA
Vice Presidents	-	H. Peterson	2HP and
	-	E. HODGKINS	VK2EH
Secretary	-	W. G. Ryan	VK2TI
Treasurer	-	W. J. McElrea	VK2UV
Councillors	-	F. Dickson	VK2AFB
	-	L. Mashman	VK2OB
	-	C. Fryar	VK2NP
	-	R. Miller	
Assistant Secretary	-	F. Gough	VK2NG
Assistant Treasurer	-	E. Treharne	VK2AFQ

Newcomers to the Council are Messrs. Hodgkins VK2EH, Mashman VK2OB, Fryar VK2NP and Treharne VK2FQ. Although new to Office these Councillors are quite well known to Amateurs and their election should greatly benefit Experimental radio in New South Wales. It is quite safe to say that the Council as now constituted is the strongest and most representative body to look after the affairs of the Institute since a few years before the outbreak of war.

The rest of the evening was devoted to a discussion on the position of the Network not forgetting the virtues of Fone. V. CW sponsored by Messrs. Jones and Meyers.

Morry Meyers VK2VM gave a short resume of his wanderings during the past two years, but unfortunately as time was getting on, what had promised to be a very interesting talk had to be cut short. For the same reason a Lecture on "Frequency Modulation" that was to have been given by the Chairman V. A. Priddle had to be postponed to the April General Meeting.

The April General Meeting of the Division will be held at V.N.C.A. Buildings on Thursday 15th April commencing at 8 p.m. and as stated in the previous paragraph a Lecture "Frequency Modulation" will be delivered by the Chairman and all Amateurs are invited to be present.



EMERGENCY COMMUNICATION NETWORK.

The first Network Traffic Exercise was held on Sunday afternoon 7th March with stations VL2JF, JI, JG, JL, JM and JN participating and the manner in which the operators attached to these stations handled the messages was very gratifying, so much so that the Radio Inspector was invited to another demonstration on the following Friday night and he, too, was more than surprised at the ability shown. On Sunday 14th March the balance of the Network stations participated, but unfortunately with one exception these stations did not exhibit the same degree of efficiency.

In an endeavor to bring all stations up to a high degree of efficiency it has been decided to grade the stations into two Divisions as follows:-

<u>"A" Division</u>	<u>"B" Division</u>
VL2JG	VL2JC
VL2JH	VL2JD
VL2JJ	VL2JE
VL2JL	VL2JF
VL2JM	VL2JI
VL2JN	VL2JK

These gradings have been made upon the performances of the stations during the message handling tests held over previous weekends. It must not be taken for granted that those stations that are at present graded in Division "A" will automatically retain that position.

It has been decided to hold exercises two nights weekly "B" Division to participate on Tuesday nights and "A" Division Fridays and a competitive spirit will be introduced. Points will be allotted under two headings - Station Operation subdivided under the following headings:- Percentage of operators present each month, Punctuality, Signal Strength, Quality of Transmission.

The Second Section will deal with Message Handling and points will be allotted for Procedure, Accuracy and Speed. At the end of each month all the points gained by each station will be added together and the six stations with the highest totals will go into "A" Division. In addition the station gaining the highest total each month will hold the W.I.A. Efficiency Pennant for the following month. In order to win this Pennant outright it will be necessary for a station to win it three times in succession or five times in all. So its up to you boys! At the present moment there are two if not three stations in "B" Division whose efforts just fall short of "A".

Opportunity is taken to thank those Country Members, particularly VK2ACT, VK2GI, VK2AMR, VK2ACP, VK2ALO, VK2AHM and VK2II for their co-operation during a recent test. Sorry boys, but we don't QSL!

What a great guy this fellow "Shorty" Higgins is. Upon a recent visit to control he noticed that the mike stand wasn't adjustable. It now is: Tix om. Any time you want a piece of 73 gauge fuse wire, just ask 2L0 and he'll oblige.

VL2JJ hit the high spots on a recent Sunday afternoon, so much so that after a lot of heartburnings they made Division "A" of the Network and not satisfied with this, went ahead and topped the score for Division "A" at the end of the First Round for the Pennant. Congratulations fellows, and keep up the good work, but a word of warning. Forget that ham "slanguage" when handling traffic or else --.

VL2JM put up a good performance in "A" Division during the First Round, but unfortunately seems to think that the operators at control write the messages down in shorthand. We don't cm. It must be perfectly legible longhand so just drop into second gear occasionally.

VL2JL was hard on the heels of 2JM but anxiety to do well apparently was the reason for several errors.

VL2JH lost a considerable number of points through not being alert. Remember chaps, and this means every operator, you should keep your receiver tuned in on Control all the time.

VL2JT has now managed to erect his beam and does he put a signal into Control. Quality is very nice too. Very keen on relaying messages. Topped "B" Division in the first round and just missed heading both Divisions. Congrats cm. By the way chaps, Charlie is a very keen cyclist and is anxious to obtain a reliable trailer.

VL2JC also did well for the "B's" but watch your procedure and alertness boys. The same remarks apply to you as to 2JH. Both stations lost points through not being alert and ready for their call.

VL2JE are still battling alone and this station has received more setbacks than any other, but nevertheless managed to raise a very respectable total under the circumstances. Keep going fellows, you never could keep a good bum down.

VL2JK, after 2JI's glowing reports on his beam has now decided that possibly the Technical Committee were right after all and D'Ono and Co. are now busy measuring feeders etc.

Well chaps here are the points for the first round:-

VL2JJ	48	VL2JC	41	VL2JG	5
VL2JL	47	VL2JH	38	VL2JN	5
VL2JM	45	VL2JE	34	VL2JK	2
VL2JL	42	VL2JF	7	VL2JD	0

Points are allotted as follows:-

Signal Strength	10	Accuracy	10
Quality	10	Punctuality	5
Procedure	10	Alertness (Speed)	5

At the end of each month a bonus will be added to those points for attendance.

So much for the first round. A few disappoints were JF, JG, whilst JI and JC did exceptionally well.

VICTORIAN DIVISION.

Since the outbreak of the war the Victorian Division has been conducting Morse Classes. Now that each branch of the Fighting Services has instituted its own training classes, the attendance at the Institute's Classes has fallen to such an extent that it was deemed advisable to discontinue with the classes.

The Institute Classes, with Mr. H. N. Stevens 3JO as Class Manager, together with a very willing band of instructors, all of whom offered their services voluntary, filled at that time a gap which unfortunately was not realised by the Military Authorities, as the standard of instruction was very high, and anyone passing through the classes eventually became a first-class operator.

The council of the Victorian Division thanks most sincerely all those Instructors who so willingly gave their services.

The Divisional Council added the sum of £5 to the amount collected at the meetings, thus making a total of £15 in the Prisoner of War Fund. This amount has been forwarded to Federal Headquarters, and will be distributed at F.H.'s descretion.

By this time all former licensed amateurs in the Metropolitan area, not already in the Services, will have received a circular in regard to a proposed ECM scheme. An early reply to this circular would be appreciated as it will help considerably the final details of the proposed scheme which Mr. Ivor Morgan 3DH is drawing up to present to the authorities in an endeavour to have such a network established in Victoria.

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The Division meets on the Third Thursday of each month at Y.M.C.A. Buildings, Pitt Street, Sydney, and an invitation is accorded to all Amateurs to be present.

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